Bacteria TMDL Development for the Rappahannock River Basin

TAC Meeting #2

September 11, 2007

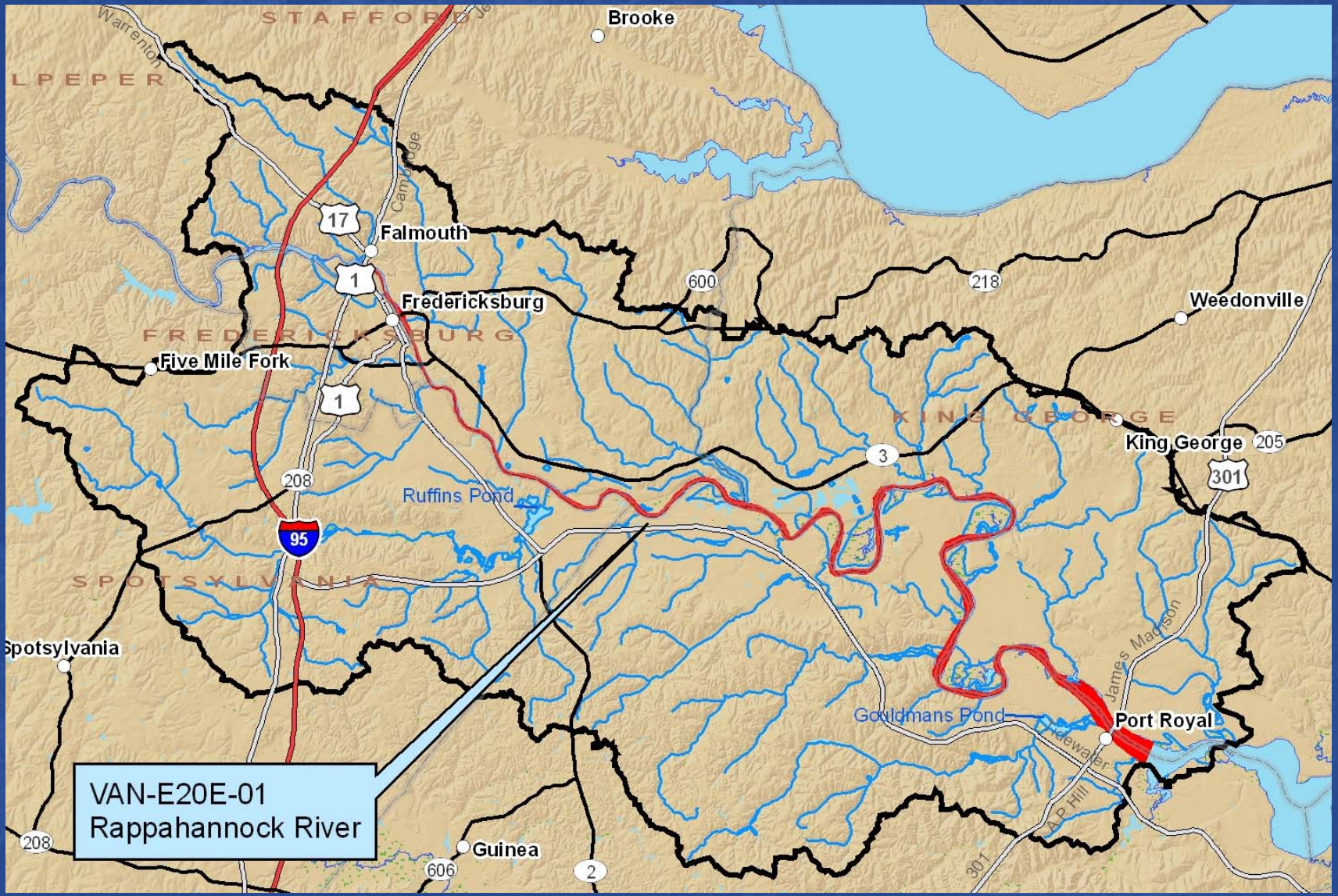
The University of Mary Washington

THE Louis Berger Group, INC.

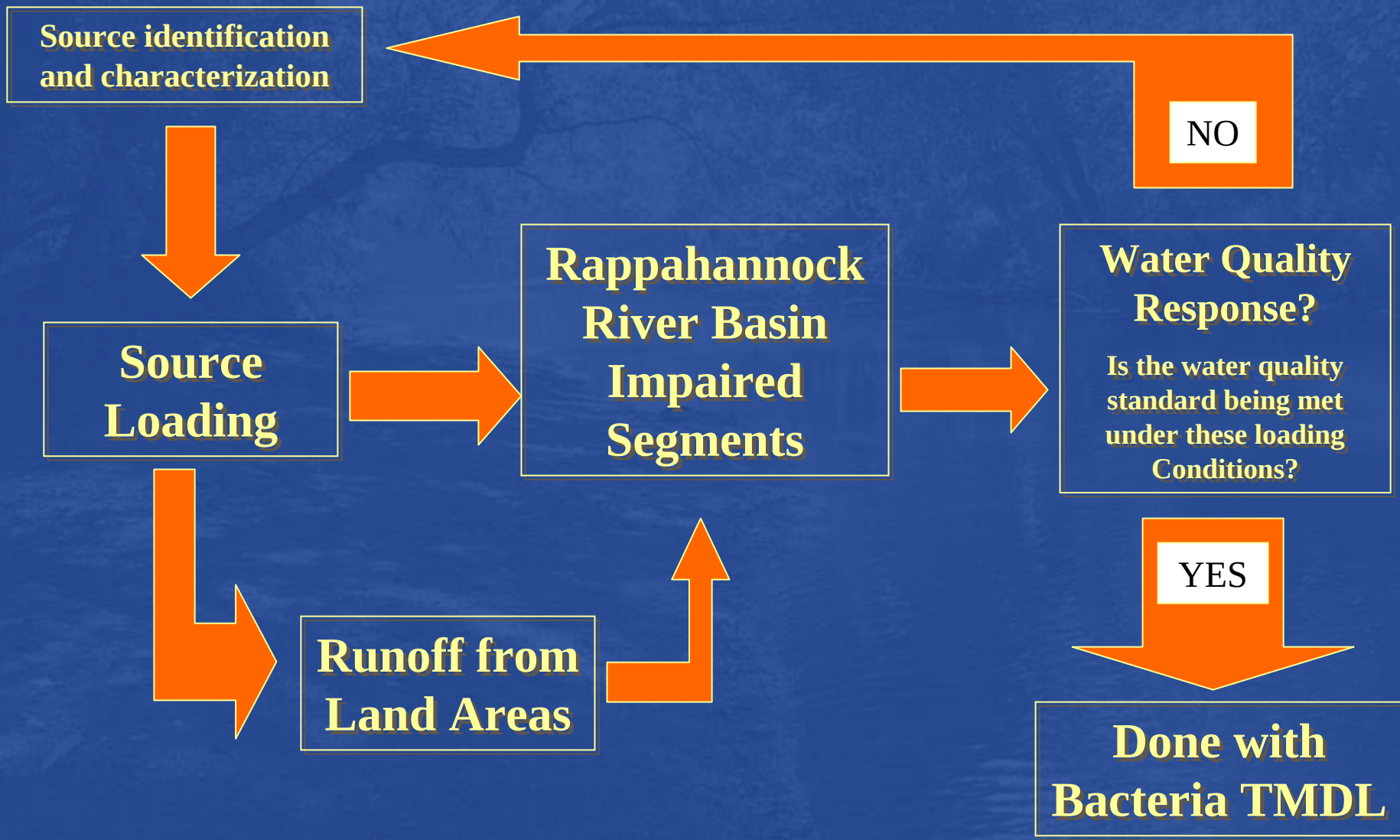
Agenda

- **Recap of TAC Meeting #1**
  - Discussed what is a TMDL? Why? and how?
  - Presented the listed segment of the tidal Rappahannock River Watershed
  - Discussed steps used in the TMDL development
  - Discussed the data used in the TMDL development
- **Discuss Land Use Reclassification**
- **Present Revised Inventory**
- **Discuss Technical Approach**

Bacteria Impairment



Linking the Source to the Instream Water Quality

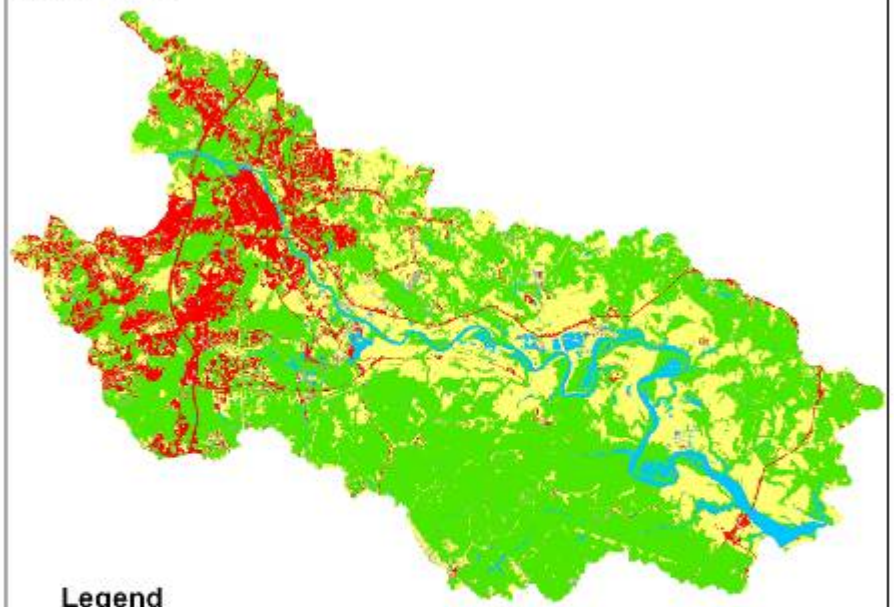


Land Use Reclassification

- New land use data available from the Virginia Department of Forestry (2005)
- Create hybrid land use layer by combining NLCD 2001 data with DOF's data
- Reclassification will better reflect growth in the watershed
- Reclassified land use will be used in TMDL development

Rappahannock River Watershed Land Use

NLCD 2001

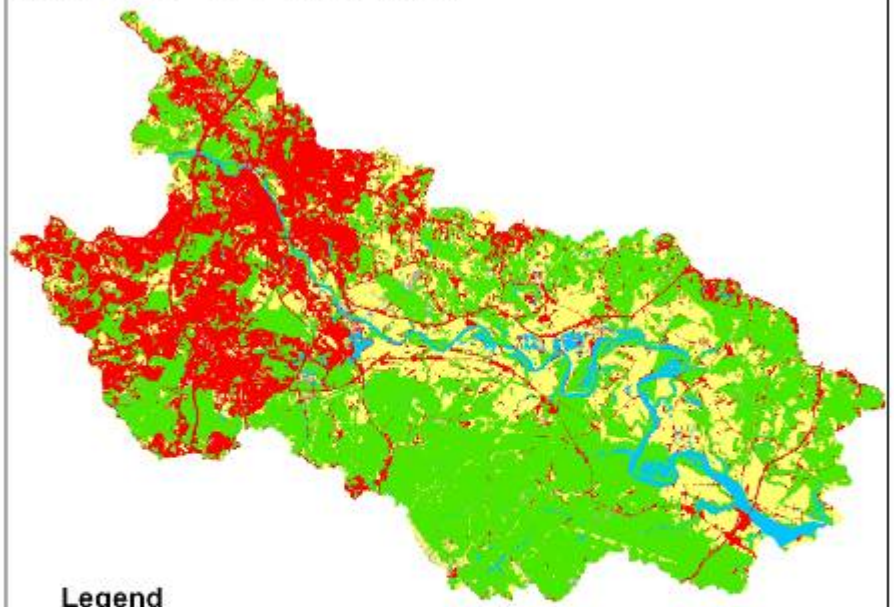


Legend

- Urban
- Water/Wetlands
- Barren
- Forest
- Agriculture

Land Cover Type	Acres
Urban	17,560
Water/Wetlands	6,409
Barren	2,174
Forest	78,137
Agriculture	42,371
Total	146,652

NLCD 2001 - DOF 2005 Hybrid



Legend

- Urban
- Water/Wetlands
- Barren
- Forest
- Agriculture

Land Cover Type	Acres
Urban	36,835
Water/Wetlands	6,131
Barren	1,466
Forest	69,579
Agriculture	32,642
Total	146,652

Bacteria Sources

- **Bacteria loading from Human Sources**
  - Permitted Sources
  - Straight pipes
  - Septic systems
  - Land Application of Biosolids
- **Bacteria loading from Livestock**
  - Livestock inventory
  - Livestock grazing and stream access
  - Confined animal facilities
  - Manure management
- **Bacteria loading from Wildlife**
  - Wildlife Inventories
- **Bacteria loading from Pets**
  - Pet Inventories

Preliminary Population Estimates and Sewage Disposal

Based on 2004 United States Census Data:

- **Population in the watershed is approximately 103,705 people**
- **There are approximately 32,488 households within the watershed**
  - 20,673 households on Public Sewer
  - 11,284 households on Septic Tank
  - 531 households on Other Means
- **Approximately 111 households in the watershed are on septic systems within 200 feet of a stream**
- **Assuming a septic system failure rate of 3%, 3 septic systems may be failing.**
- **Failed septic systems are considered straight pipes if located within 200 feet of a stream and are assumed to be directly discharging sewage into the stream**
- **Septic system design flow is 75 gal per person per day**

Revised Septic Tank Estimates in the Watershed

County/City	Number of Septic Tanks
Spotsylvania	2,318
Fredericksburg	41
Stafford	2,700
Caroline	880
King George	In Progress

Source: County Data

Rappahannock River Point Source Inventory

(VA Department of Environmental Quality)

Category	Permit Type	Count (Active or Application)
VPDES	Industrial	5
	Municipal	12
General Permits	Single Family Domestic Sewage	3
Total		20

Land Application of Biosolids

Year	Caroline	King George	Spotsylvania	Stafford
2005	10,720	5,645	6,029	0
2006	8,714	3,595	646	0

- **Biosolids applied to:**
  - Cropland
  - Pasture

Source: VDH

Loading from Livestock

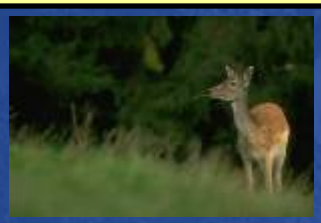
Fecal coliform produced by livestock can enter the watershed through four pathways:

1. **Manure deposited on land by grazing livestock is washed off during rainfall events**
2. **Manure directly deposited into the stream by livestock with direct access to the stream**
3. **Manure deposited by livestock in confinement is typically collected, stored and applied to the landscape**
4. **Wash-water and waste from the drainage systems of confined animal facilities**

Livestock Type	Caroline	King George	Spotsylvania	Stafford	Total
Beef cows	-	50	150	350	550
Milk cows	-	-	-	-	-
Hogs and pigs	8	6	-	2	16
Sheep and lambs	12	20	-	-	32
Chickens	37	30	30	30	127
Horses and ponies	50	150	200	100	500

Based on estimates from USDA Service Center in Fredericksburg, VA.

Wildlife Inventory



Wildlife type	Population Density	Habitat Requirements
Deer	0.047 animals/acre	Entire Watershed
Raccoon	0.07 animals/acre	Within 600 feet of streams and ponds
Muskrat	2.75 animals/acre	Within 66 feet of streams and ponds
Beaver	4.8 animals/mile of stream	
Goose	0.02 animals/acre	Entire Watershed
Mallard	0.002 animals/acre	Entire Watershed
Wood Duck	0.0018 animals/acre	Within 66 feet of streams and ponds
Wild Turkey	0.01 animals/acre	Entire watershed excluding farmsteads and urban land uses

Source: Map Tech, Inc., 2001, Goose Creek TMDL

Preliminary Wildlife Estimates

Wildlife Animal	Caroline	King George	Spotsylvania	Stafford	Fredericksburg	Total
Deer	2,035	1,678	1,568	1,313	298	9,058
Raccoon	1,875	1,524	1,401	1,196	176	8,225
Muskrat	8,102	6,585	6,054	5,169	762	35,544
Beaver	884	718	660	564	83	3,877
Goose	173	143	133	112	25	771
Mallard	6	5	4	4	1	26
Wood duck	5	4	4	3	0	23
Wild Turkey	433	357	334	279	64	1,927

Estimates are based on NLCD 2001 land use data and distribution estimates from DGIF

Pet Estimates

Pet inventories based on:

- Cats: 0.598 per household American Veterinary Medical Association (AVMA) estimates
- Dogs: 0.543 per household American Veterinary Medical Association (AVMA) estimates

In the Rappahannock River Watershed there are approximately:

- 17,641 Dogs
- 19,266 Cats

The load estimated by daily fecal coliform production rates:
4.09 x10^9 cfu/day per animal for dogs.
504 cfu/day per animal for cats

Source Loading Estimates

Source Loading Estimates

- Determine the daily fecal coliform production by source
- Estimate the size/number of each source
- Determine whether the source is
  - Direct Source
  - Indirect Source
- Calculate the load to each land use based on a monthly schedule and for each source
- The sum of all the individual sources is the total load

Daily Fecal Coliform Production by Source

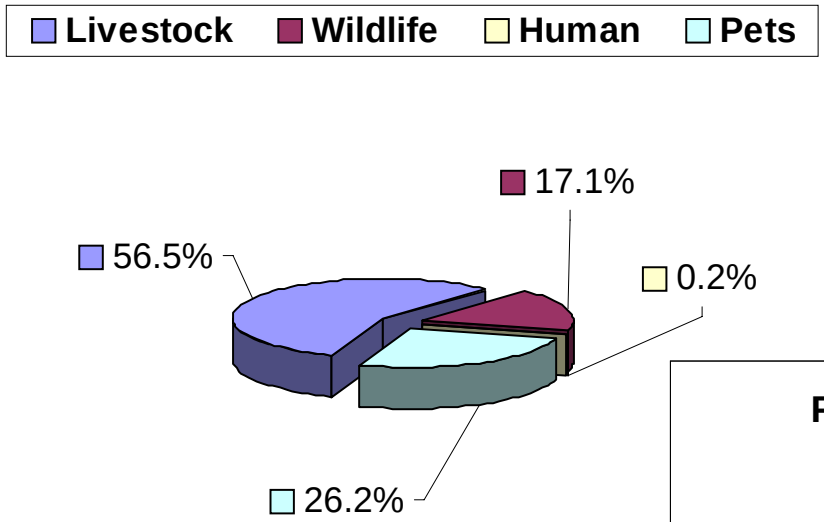
Source	Fecal Coliform Content in Fecal Matter (million) (cfu/day)
Human	1,950
Pet	450
Horse	420
Beef Cattle	33,000
Dairy-Milked or dry Cow	25,200
Dairy-Heifer	11,592
Sheep	27,000
Deer	347
Raccoon	113
Muskrat	25
Beaver	0.2
Goose	799
Duck	2,430
Mallard	2,430
Wild Turkey	93
Hog	10,800
Chicken (Layer)	136

Source	The Equivalent Number of Sources to One Beef Cow
Human	16.92
Pet	73.33
Horse	78.57
Beef Cattle	1.00
Dairy-Milked or dry Cow	1.31
Dairy-Heifer	2.85
Sheep	1.22
Deer	95.10
Raccoon	292.04
Muskrat	1,320.00
Beaver	165,000.00
Goose	41.30
Duck	13.58
Mallard	13.58
Wild Turkey	354.84
Hog	3.06
Chicken (Layer)	242.65

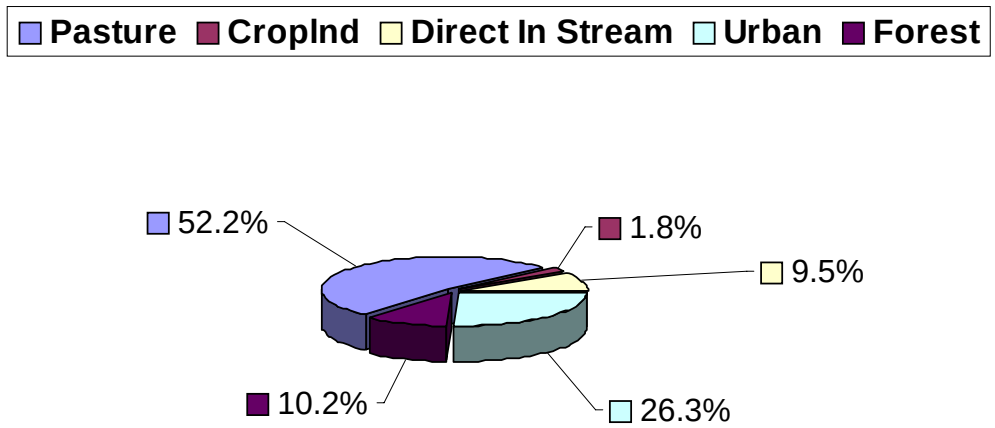
NOTE: The fecal coliform content is based on analysis of the fecal matter from these sources.

Sources: ASAE, Map Tech, Metcalf & Eddy,

Fecal Coliform
Total Available Daily Loading by Source



Fecal Coliform Total Available Daily Loading by Land Use



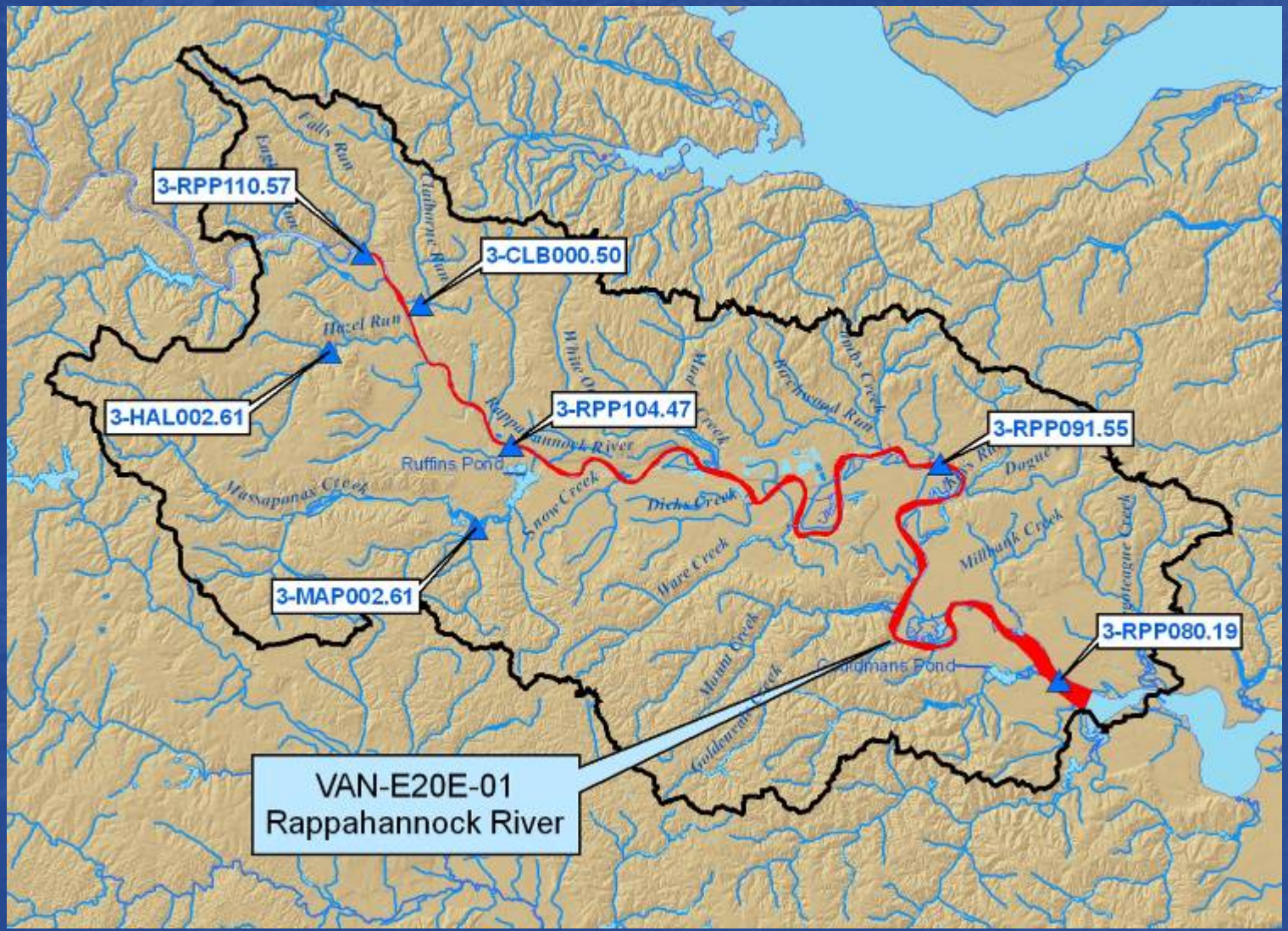
Bacteria Source Tracking (BST)

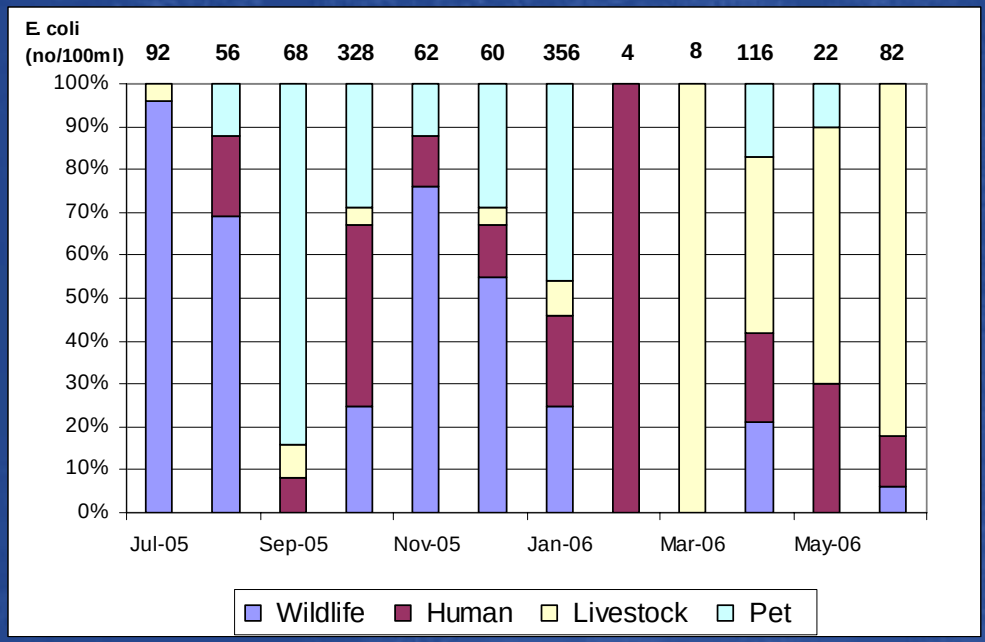
- **Conducted monthly (Jul 2005 to Aug 2006) at 7 stations**
  - 4 stations on the Rappahannock River
  - 1 station on Massaponax Creek
  - 1 station on Hazel Run
  - 1 station on Claiborne Run

- **A total of 12 sampling events were collected at each station**

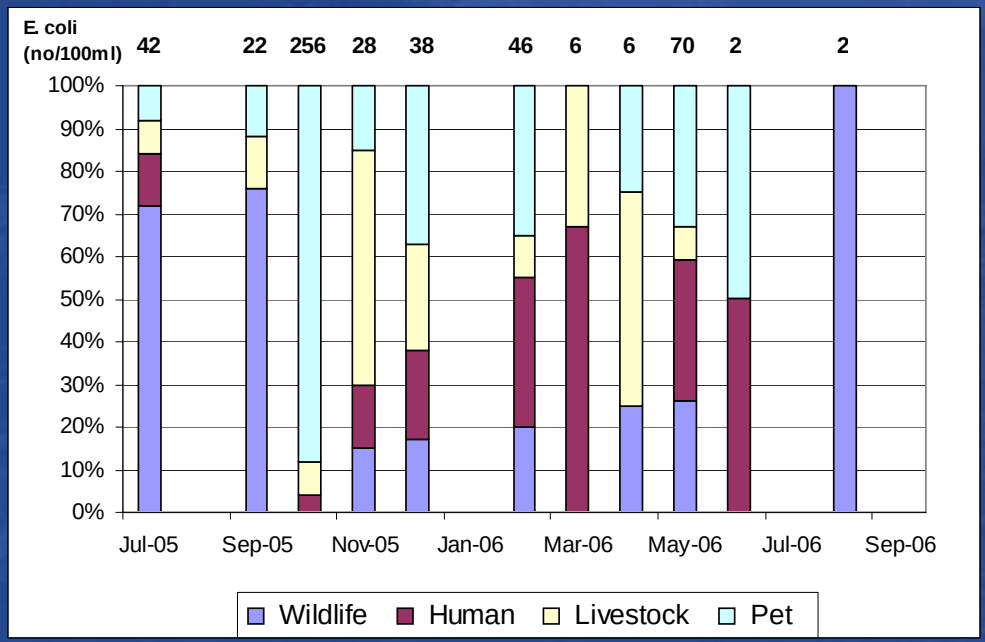
- **Results indicate that bacteria from human, livestock, wildlife, and pet sources is present in the watershed**

BST Sampling Stations

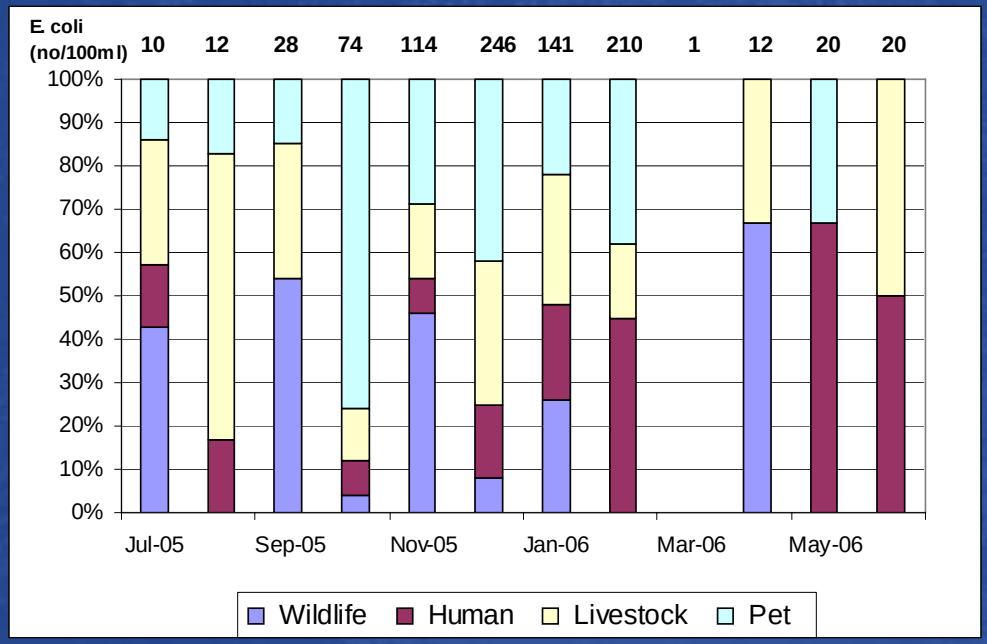




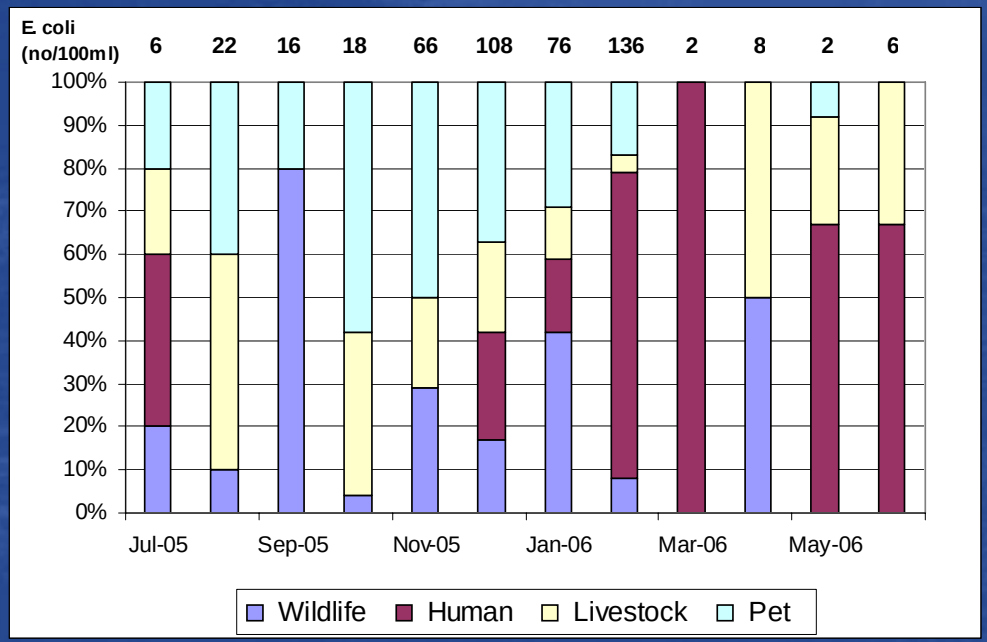
3RPP110.57
BST Distribution



3RPP104.47
BST Distribution



3RPP091.55
BST Distribution



3RPP080.19
BST Distribution

Modeling Strategy

The following approach was approved by DEQ and EPA on August 16, 2007

Watershed Model

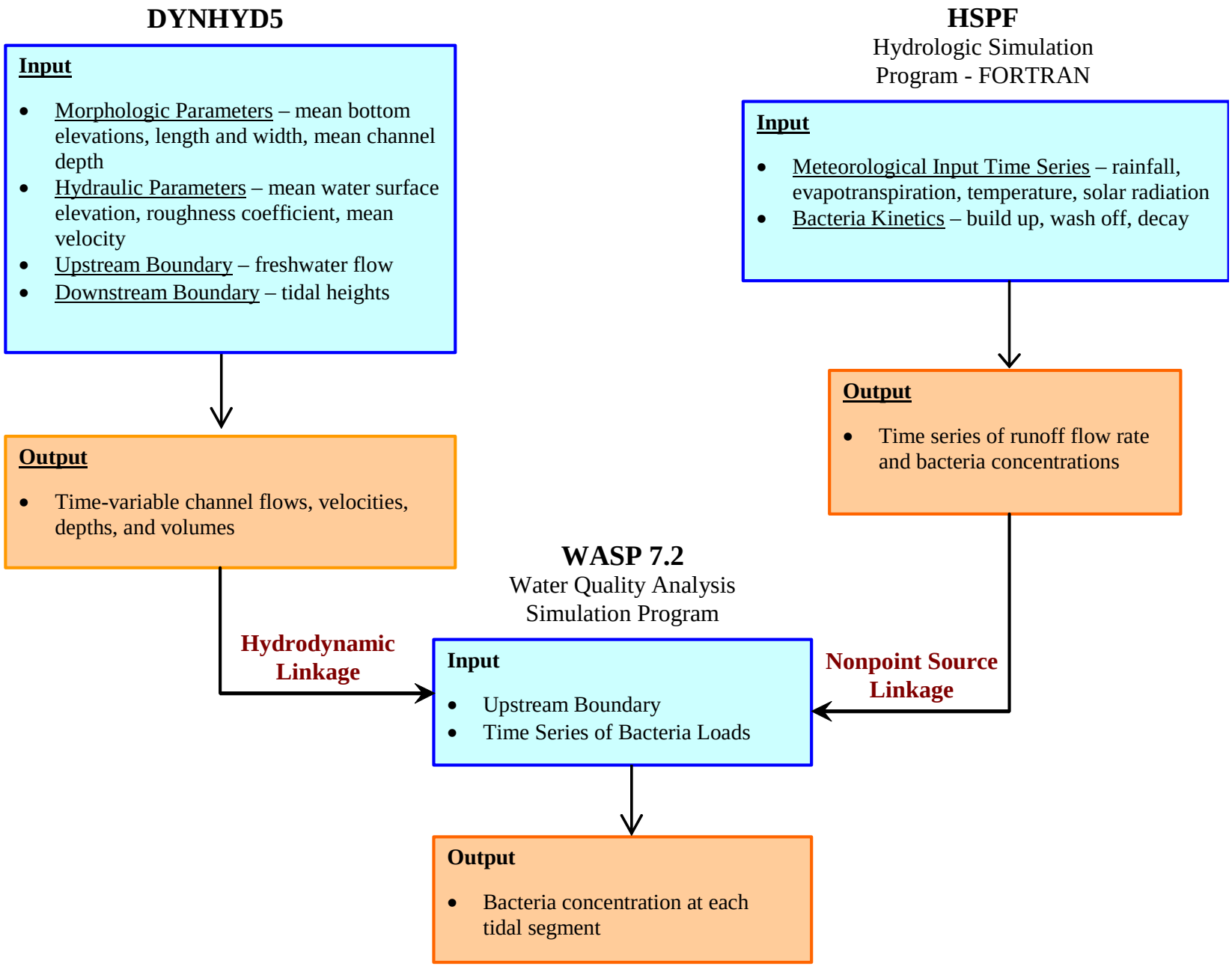
- HSPF
  - Hydrologic Simulation Program FORTRAN (HSPF) model (Bicknell et al., 2001) to simulate watershed loading processes

Instream Model

- WASP 7.2
  - The Water Quality Analysis Simulation Program model (Wool et al., 2006) to simulate instream water quality processes for the tidal reaches
- DYNHYD5
  - Dynamic Estuary Hydrodynamics Program (DYNHYD5, a sub-model to WASP7.2), to simulate velocity, volume, and water depth under varying river flow and tides

Model Descriptions

- HSPF
  - Hydrologic, watershed-based water quality model
  - explicitly accounts for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading
  - runoff portion of the model will be used to generate the NPS loads to the Rappahannock River
- WASP7.2
  - Dynamic compartmental modeling program for aquatic systems
  - Time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange can be represented
  - Simple Toxicant sub-model will be used to simulate the fate of fecal coliform in the Rappahannock River. Simple Toxicant allows a user to specify first-order reaction rates for reactions of each of the chemicals simulated.
- DYNHYD5
  - Link-node hydrodynamic model simulating velocity, volume, and water depth under river flow and changing tidal events
  - Solves the equations of conservation of mass and energy by the method of finite differences to predict water velocities, flows, heights, and volumes
  - Inputs include
    - initial surface elevations, bottom elevations and segment volumes;
    - channel lengths, widths, areas, roughness, orientations, and initial velocities;
    - variable or constant boundary flows;
    - downstream boundary surface elevations and
    - wind parameters

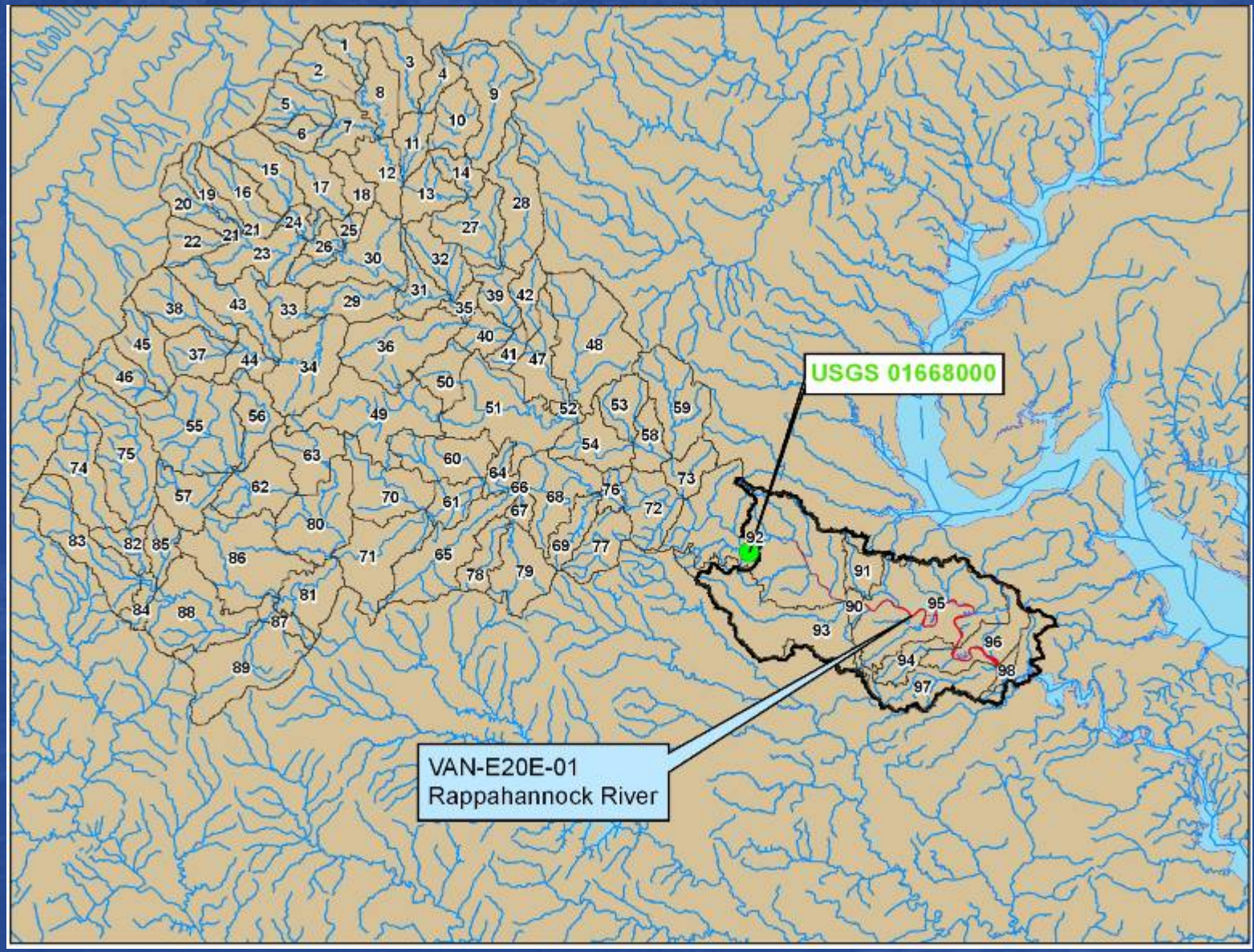

DYNHYD5
Input
Morphologic Parameters – mean bottom elevations, length and width, mean channel depth
Hydraulic Parameters – mean water surface elevation, roughness coefficient, mean velocity
Upstream Boundary – freshwater flow
Downstream Boundary – tidal heights
Output
Time-variable channel flows, velocities, depths, and volumes
HSPF
Hydrologic Simulation Program - FORTRAN
Input
Meteorological Input Time Series – rainfall, evapotranspiration, temperature, solar radiation
Bacteria Kinetics – build up, wash off, decay
Output
Time series of runoff flow rate and bacteria concentrations
WASP 7.2
Water Quality Analysis Simulation Program
Hydrodynamic Linkage
Nonpoint Source Linkage
Input
Upstream Boundary
Time Series of Bacteria Loads
Output
Bacteria concentration at each tidal segment

HSPF Model Setup

- **Rappahannock River Watershed delineated to 98 model subwatersheds for bacteria loadings**

- **Hydrologic Model Calibration/Validation**
  - USGS Flow Station 01668000
- **Water quality Model Calibration/Validation**
  - Using DEQ water quality stations on tributaries
- **Weather data:**
  - NCDC data from Fredericksburg STP and National Airport

HSPF Model Segmentation

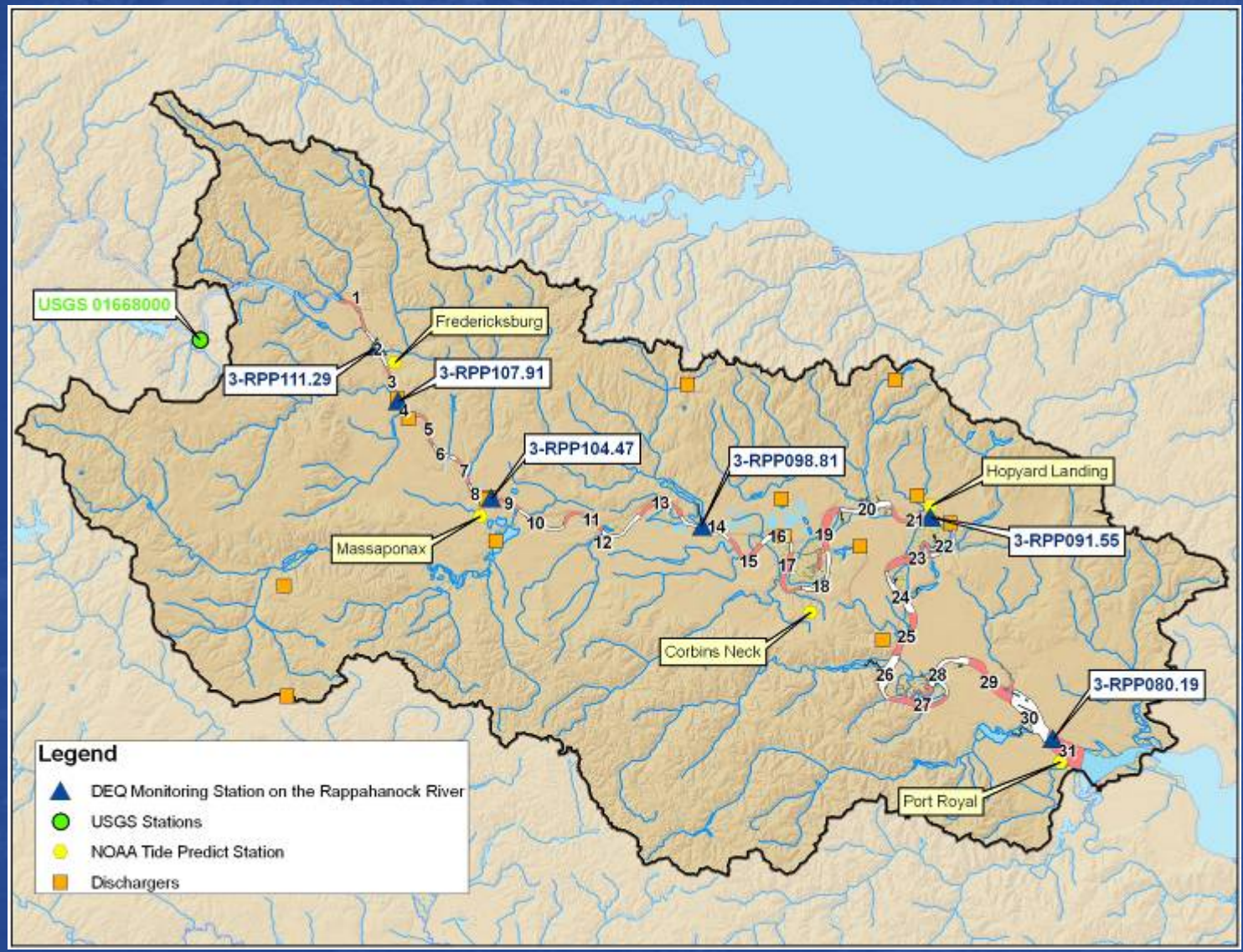


DYNHYD5/WASP7.2 Model Setup

- **31 model segments were defined based on the location of water quality and hydrological stations as well as dischargers on the impaired segment of the Rappahannock River**

- **Hydrologic Model (DYNHYD5)**
  - USGS Flow Station 01668000 for freshwater input
  - NOAA Tide Prediction Tables (Water Heights)
  - NOAA Bathymetry Data
- **Water quality Model (WASP7.2)**
  - Using the 6 water quality stations located on the impaired segment

DYNHYD5/WASP7.2
Model Segmentation



Next Steps

- **Complete data collection**
- **Develop:**
  - Bacteria source loading estimates (Fecal Tool)
  - Model input parameters:
    - Hydrology and water quality
  - TMDL scenarios
- **Prepare Draft TMDL Report**

Comments? Feedback?

- Public Comment Period for this meeting extends from September 11, 2007 to October 10, 2007.
- All comments should be in writing. Please send them to:

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